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OFFICE OF STRATEGIC SERVICES

Research and Analysis Branch

R & A No. 1616

THE GERMAN ANTI-FRICTION BEARING POSITION

A review of our present knowledge of the European ball and roller bearing position made in order to establish the areas in which further investigation would be most profitable and to point up the most important phases of the problem for the consideration of those working on it.

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THE GERMAN ANTI-FRICTION BEARING POSITION

A. Preliminary Statement. This review of our knowledge of the European Axis ball and roller bearing position has several purposes. Among them are:

1. An analysis of the German bearing consumption pattern in absolute terms, based on fragmentary data, but leading, we believe, to the conclusion that the German pre-raid bearing position is considerably easier than analyses made in percentage terms have suggested. Although we are unable at this time to do more than point out the possibilities we believe that German bearing requirements can be comfortably met from the pre-raid capacity/available to the Germans and only if capacity is smaller or production does not approach capacity can there be any general bearing shortage.

2. A listing of the plants available to the Germans and the capacity of each plant as known to us at present.

3. A brief statement of the methods which we believe should be followed in seeking a solution to the problem which is suggested in this note.

B. Statement on Method. A statement of the methods which we believe should be followed in a study of this nature is relatively easy and however difficult these methods may be to apply we feel they should be stated to clear

our consciences of the burden of arbitrary assumptions. Briefly we think that accurate and detailed counts of ball and roller bearings in enemy equipment should be made. Care should be taken in making such a count to include all components and instruments, attachments, small motors, etc. Information on enemy practise or U.S. or British practise on spares will be necessary to compile accurate estimates of the use of bearings in enemy aircraft (various types), tanks, trucks, fire control equipment, artillery, etc. It will be well to note the exact location of each bearing and to explore the possibility of substitution of plain bearings for ball or roller bearings and the possibility of eliminating bearings completely from certain uses.

A more ambitious undertaking would involve examination of a number of items of enemy equipment of any one type, several Mk IV tanks for example. If several Mk IV tanks were examined and their bearings counted and the maker of each bearing identified it might be possible to build up a sample of bearing use for each important manufacturer. The aero-engine study of 31 May 1943 attempted something along these lines but for several reasons we do not believe it to be completely reliable.

The body of the paper follows. It is divided into four sections. They are:

I. European Axis Capacity and Production.

SECRET

II. European Capacity and Military Production Programs and U.S. Capacity and Military Production Programs.

III. A Tentative German Consumption Pattern.

IV. Some Tentative Conclusions.

I. EUROPEAN AXIS CAPACITY AND PRODUCTION.

Recent intelligence on new ball and roller bearing plants and reports of the expansion of existing plants suggest that the present estimates of Axis bearing capacity need reconsideration and revision. We are, therefore, submitting a list of known and reported plants in Germany, Italy and France with the various reports of their daily output and some comment on the source and validity of the reports. In general our list was compiled by FEA and rests largely on the knowledge of American bearing men.

The capacity estimates are stated in terms of the SKF standard bearing and their estimated 10 hour machine day. Our only hope for revision of these estimates seems to be either intelligence or further contact with people who know the plants, among whom SKF men in Sweden seem to be the most likely source. Little or no additional reliable information is available in this country.

The list does not include industrial plants, among them some automotive, agricultural machinery, etc. manufacturers who make bearings for their own use only. Also omitted is the probably substantial output of separate non-bearing balls and rollers which is not known to us. In the United States large quantities of balls and rollers are produced for export where they are frequently used in complete bearings but also for separate use in explosive controls, check valves, steering gears, universal joints and tank and naval turrets.

A recent AI-K paper entitled "The German Bearing Production - August 1943" listed a number of plants of both these natures.

SECRET

EUROPEAN ANTI-FRICTION BEARING CAPACITY

Plant Name	Location	Estimated Daily OutPut (000 pieces of equipment Standard size)	Type of Bearing Produced	Comment
Germany				
Fischer Combine				
Kugelfischer	Schweinfurt	100	ball and roller	M.E.W. estimate corroborated by New Departure officials in this country.
Jaeger	Wuppertal	10	large)	M.E.W. estimate Jaeger and Nord-Deutsch together produced 1500 per day according to S.K.F. officials in this country.
Nord-Deutsch	Berlin-SW 36	5	roller) ball)	
VKF Combine				
VKF I and II	Schweinfurt	100 bearings and balls for 30 additional bearings for other VKF plants	ball and roller	M.E.W. estimate is 100 bearings. SKF officials stated that VKF Schweinfurt also supplied balls for 25-35,000 bearings to other VKF plants. Numerous ground reports of materials received at Norma from Schweinfurt confirms this as does the report of Garr, formerly a director at Steyr, that VKF Schweinfurt supplied them with balls
Norma	Stuttgart	30	ball & roller	SKF officials in this country. MEW gives the output as 60,000 bearings a day.

SECRET

Plant Name	Location	Estimated Daily Output (000 pieces of equipment Standard size)	Type of Bearing Produced	Comment
Deutsche Waffen	Berlin NW7	small	ball & roller	SKF officials - also Jurgensmeyer 1/
Riebe	Berlin-Weissensee		ball & roller	Listed by Jurgensmeyer as taken over by VKF, presumably still in production
Riebe	Berlin-Wittenau			Listed by Jurgensmeyer as taken over by VKF and dissolved, (aufgelöst)
Rhineland	Dusseldorf	small	ball & roller	SKF officials
Norma	Berlin			Listed by Jurgensmeyer - probably only a sales office
Hollman	Wetzler		spindle	Listed by Jurgensmeyer as taken over by NKF and dissolved. Bern reports an employment of 500 workers roughly equivalent to 5000 bearings per day. This estimate came from SRO officials in Switzerland.
VKF-Erkner	Berlin-Erkner	30	ball & roller	SKF officials and engineers who had been through the plant, reported to make only large bearings so actual output as opposed to equivalent standard size is probably smaller. MEW estimated 15,000 bearings per day.

SECRET

Plant Name	Location	Estimated Daily Output (000 pieces of equipment Standard size)	Type of Bearing Produced	Comment
DKF	Leipzig	10		MEW estimate
Fuller	Nurnberg	5	ball & roller	MEW estimate. Recently reported to have expanded up to 20-25,000 bearings per day. The employment figure in this report, 500 to 1,000 men, suggests the previous estimate still holds.
Mannesmann	Neunkirchen	10		MEW estimate. Not listed by Jurgensmeyer
Robert Kling	Wetzler	small	special cylindrical roller	Listed by Jurgensmeyer
Prazisionswerke	Bielefeld		ball	Listed by Jurgensmeyer; a new plant in 1939 according to Hughes, President of New Departure, who was in Germany in 1939.
Universal	Berlin		ball	listed by Jurgensmeyer a new plant in 1939 according to Hughes
Steyr-Daimler-Puch	Steyr	6		SKF officials. This plant has undoubtedly expanded. Recent reports corroborated by independent analysis suggest a present output of 50,000.

SECRET

Plant Name	Location	Estimated Daily Output (000 pieces of equipment Standard size)	Type of Bearing Produced	Comment
Rumored Plants in Germany				
VKF	Berlin-Neukolln Kopenickerstr			Bern Report, presumably SKO officials reported 2000 workers or roughly 20,000 bearings.
Ball	Berlin-Neukolln			Bern report: 200 workers or roughly 2000 bearings. Manufactures small rollers
	Schwardorf near Regensberg			Bern report ground sources of dubious reliability
	Egertal Linz Troistadt			Bern report source: "reliable Czech"
France				
SKF - C.A.M.	Paris-Bois Colombe	20	ball & roller	SKF officials estimate after consulting engineer who had been in plants
	Paris-Ivry Port	20	ball & roller	MEW estimate was 15,000 each Bern report suggest a figure of 30,000 in each plant.
SKF - Malicet et BLN	Paris-Aubervillers	10	ball & roller	SKF officials in this country; estimate corroborated by head of French branch of Potter and Johnson
Timken	Paris-Aenieves	10	Tapered roller	SKF estimate

SECRET

Plant Name	Location	Estimated Daily Output (000 pieces of equipment Standard size)	Type of Bearing Produced	Comment
RCF (Crochet) Madella Lyon	La Ricamarie) Larallois) Villeurbanne)	10	ball & roller	
SRO	Annecy	10	ball & roller	SKF estimate of its engineers familar with plant, corroborated by SRO Switzerland. Reported sabataged during raid of 11/10/43 and inactive at present
Italy RIV	Turin Villar Perosa	(CO)	ball & roller	SKF estimate
Imports	Sweden	13		
	Switzerland	5		
Total		470		

1/ Jargensmeyer: Die Walslage, Druck der Universitatsdruckerei, H. Sturtz A. G., Wurzburg, undated. Jurgensmeyer is the outstanding academic authority on the European bearing industry. His list includes all the plants on our list except Manesmann Neunkirchen and the plants whose existence is still a matter of speculation. Since two of the plants on Jurgensmeyer's list were new in 1939, the list was probably made not much earlier than that year. The list also includes the type of bearing produced but does not include any estimates of the size of the output.

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II. CAPACITY AND MILITARY PRODUCTION PROGRAMS

Almost the entire present capacity of Europe, as shown in the foregoing list, has been available to Germany since the middle of 1940. It has been customary to allow for Italian use of five-sixths of the 60,000 pieces produced each day in the Italian plants. Thus, on a monthly basis (25 working days), German consumption will have been between 10,000,000 and 10,500,000 ball and roller bearings. Although recent intelligence reports have mentioned plant capacity in addition to that previously assumed, principally at Steyr in Austria, the accepted figures refer to capacity in existence since 1940. The last important expansions at Schweinfurt and at the Erkner plant were reported completed in April 1940. The importance of these facts is understood when we study the United States production figures for the same period.

These figures show that in 1939 United States output was below that credited to Axis Europe. There has since been a tremendous expansion, brought about thru increased utilization of existing plant and a building program estimated to cost $60,000,000.

The data in the table below are estimates based on Census and War Production Board reports. Because the available figures were incomplete, it was necessary to estimate many of the annual and monthly items. All figures marked with an asterisk were estimated by using a conversion factor between dollar value of output and numerical output.

This factor is ~1.10 per bearing for the period through 1939 and ~1.22 for the period since 1939. All figures are for all bearings, not for a "standard bearing". The implications of this point are discussed below.

TABLE I

U. S. ANTI-FRICTION BEARING PRODUCTION
1933-1943

	Dollar Value	Units
1933	40,530,143	*36,800,000
1935	86,571,271	*78,700,000
1937	124,013,530	*112,700,000
1939	105,270,164	*95,700,000
1941	*310,565,810	254,562,140 1/
1942		
January		21,661,233
February		20,320,488
March		22,398.667
April		21,728,807
May		21,093,706
June		22,125,260
July		*22,125,000
August		*22,500,000
September		*22,750,000
October		*23,000,000
November		*23,500,000
December		*24,000,000
Total	*325,987,856	*267,203,161
1943		
January	*29,890,000	*24,500,000
February	30,446,887	*25,000,000
March	33,913,418	27,664,689
April	33,534,229	26,687,340
May	32,677,000	26,369,993
June	33,534,000	28,234,464
July	34,916,824	28,117,845
August	34,011,212	28,548,071
September	35,765,490	28,834,000
October	36,128,639	29,532,334
November	36,600,000 2/	30,000,000 2/
December	36,600,000 2/	30,000,000 2/
Total	408,017,699 2/	333,488,736 2/

1/ Very large exports to U. K.
2/ Estimated
* Estimated by conversion factor.

The expansion of U.S. bearing output and its present extremely high level should not mislead us as to the German position. If, as we assume, German controlled plants have been operating at capacity, German Europe today has a larger output relative to armament production than has the U.S. A few rough comparisons are sufficient to illustrate this point:

Estimated Monthly Production of Bearings and Selected Items

	U.S.	German Europe	Per Cent Europe of U.S.
A-F Bearings	30,000,000	10,500,000 1/	35
Aircraft	9,300	2,500	27
Trucks and Trailers	67,000	15,000 2/	22

These comparisons fail to take into consideration the differences in bearing use for each airplane or truck, and the difference in types of aircraft, trucks, etc. Nevertheless they show, it seems to us, that the German bearing position may well be fairly easy if the accepted production estimates are valid. The reportedly "extravagent" use of bearings in tanks, aircraft elevator control races and in the cocking and firing mechanisms of aircraft machine guns may partially confirm this view. The following section attempts a more detailed analysis of the German bearing consumption pattern with the aid of more specific information.

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1. Conservative estimate on undamaged plant basis in term of standard bearings.
2. This figure is used for illustrative purposes and is not the OSS estimate. It is probably too large.

SECRET

TABLE II

Estimated Monthly U. S. Bearing Consumption Pattern
and Selected Production Programs

End Item	No. Scheduled* Nov.-Dec.-Jan. Monthly average	Total Bearings Used- Percent	Number
Aircraft	9,300	50	15,000,000
Army Ground Use-		23	6,900,000
Principal Items:			
Military Trucks and Trailers 1/	53,000		
Tanks	1,600		
Armored Cars	1,400		
Scout Cars & Carriers	4,000		
Self-Propelled Artillery Chassis (all types)	2,000		
Artillery over 37 inch	5,400		
Fire control (Directors, height finders, etc.)	4,200		
Naval Use (excluding naval aircraft)		8	2,400,000
Industrial and Civilian		14	4,200,000
Export		5	1,500,000
		100	30,000,000

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* More information of this type is available in Official Munition Production of The U. S. The figures shown are only indicative of magnitudes as questionable additions have been made.

1/ Civilian and Export Trucks and Trailers are an additional 9,000 per month.

III. GERMAN BEARING CONSUMPTION PATTERN

There follows a statement of the rough reasoning by which we have been led to question the seriousness of the German bearing position. Throughout this section extremely generous estimates of German bearing use and German production of military items have been used. The estimates of production of military items are not the OSS estimates and should not be taken as such. The extremely large and most unlikely estimates have been used to demonstrate a thesis which, if successful under such conditions, will be valid when more conservative and accurate estimates of military production are used. It is expected that these more accurate estimates of military production and similar estimates of German bearing use will be substituted as work on this problem proceeds.

All figures are given in terms of monthly rates of production. U.S. bearing figures, as in the above section, are actual bearings and military item figures are schedules with an average schedule for several months used to allow for lag and for short term fluctuations of production. In each section we attempt to present the information on which we have based our estimates of German use and to show by how much we believe our generous estimates err. Naturally direct evidence such as should be available in England, will permit great improvement of these figures.

A. Aircraft. United States aircraft consumption of bearings, if by this we mean the number of bearings going monthly to all programs of the U.S. aircraft production agency, is approximately 1600 per plane. This includes spares and all equipment procured by the Aircraft Resources Control Office, that is, all equipment

special to army or navy air force use. We hope soon to have accurate and complete tabulations of the number of bearings and their location in the principal types of U.S. aircraft. We have now only rough figures for a few types. These are figures for complete aircraft including equipment but with vague or no provision for spares. They include an estimate of 3800 for a four engine bomber, probably the B-17; 1035 for the B-25 two engine bomber; and 822 for the P-38 two engine fighter.

Total monthly U.S. consumption of bearings for aircraft is approximately 15,000,000; four engine bombers consume approximately 3800 x 1000 bombers or 3,800,000. The remaining 11,200,000 bearings are used for 8300 aircraft of other types, or about 1350 bearings are used for each aircraft of other types.

Using this data, in the present absence of better, we can arrive at a first approximation of German aircraft use. German aircraft production is now heavily concentrated in the single and two engine fighter classes. On the whole there is probably also a differential as to bearing use which unfortunately must rest at present on a vague belief, on the use of bearings in place of jewels in U.S. planes and similar qualitative and imprecise ideas. We therefore are using 1100 bearings per plane as an approximation for German aircraft use. We feel this is a maximum figure. Estimating German production at 2500 aircraft per month we have total German aircraft bearing consumption at approximately 2,750,000 per month.

In arriving at this figure we have assumed that German bearing practice in aircraft is generally similar to that of the U.S. If,

as Charlie Kindleberger believed possible, they use substantially fewer bearings in airframes, the bottom may drop out of the bearing analysis and aircraft bearing use would be much smaller than we take it to be. For that reason a brief discussion of the use of bearings in engines may be helpful.

U.S. engines, we believe now, have between 50 and 100 bearings. This includes superchargers, magnetos and no other major accessories. Spare bearings for engines in the U.S. average about 100 per cent and over that for some bearings. We expect, as we said above, to have much better data on this problem in the near future.

Our data on German engines is very scanty. We have looked thru a number of RAE (Farnborough) studies which were made without special attention to the total number of bearings. EAM/44, May 1941, shows 24 plus bearings in a Daimler-Benz 601A. Ed Mayer says this engine used rollers lavishly in the crankcase connecting rod assembly. EAM/60 reported 5 plus bearings in a Junkers propellor.

Despite our feeling that aero-engine bearings may be closer to 50 than 100 in German planes for the purposes of this paper we can assume that requirements, including 100 per cent spare bearings, are approximately 200. The Air Section estimates engine production at 4500 per month. Thus we can tentatively take engine bearings at not more than 900,000 per month, about one-third of total aircraft bearing requirements and even using this high estimate only between one and two days of the monthly production available to the Germans.

Our principal reason for including this somewhat digressive note, beyond the fact that it focuses the engine-frame problem, is in the comment it offers on the May 1943 aero-engine bearing study. We believe that it is unwise to place very much confidence in estimates of the use of the bearings produced by individual plants on the basis of the small and specialized sample of this study. The nature of the bearing manufacturing process, especially the batch process and the relative flexibility of machines seem to be the main considerations bearing on this point.

B. Tanks. Hoeffding's note of Oct. 13, 1943 seemed to indicate about 50 bearings per tank which checks with rough approximations we have heard here. We may be able to get better data but opportunities in England should be better. We are using a figure of 200 per tank including spares. Taking tank production at 1000 per month, well above G.I.U.'s estimates, we get tank bearing consumption at 200,000 per month.

C. Armored Cars. Assuming 100 per armored car, including spares and 1000 armored cars per month (very high estimate) we get armored car consumption at 100,000 bearings per month.

D. Trucks. Both Hoeffding's data on British trucks and what little we have so far picked up here indicates that 50 is a fair average for truck bearings. We have used 100 bearing per truck, including spares. We have used a figure of 15,000 trucks produced each month. This is considerably in excess of the G.I.U. estimates and is certainly more than ample, with the high rate of bearings per truck we have chosen, to account for a spare part program of tremendous size. The truck bearing total therefore is shown at

1,500,000 per month. The omission from our list of plants and our production total of "captive" bearing manufacturers, that is those manufacturers of bearings who use them in end items which they also produce, is probably of greatest importance in the case of truck manufacturers, who seem most likely to make some of their bearings for themselves. To the extent that they do so our figures are too high.

E. Fire Control and Artillery, including Ground Radar. This is a very uncertain field. We are using a figure of 250,000 bearings per month. Artillery production, including A/T and AA is not well known but the MEW at one time placed it at 3300 including a good many very light guns, which would use few bearings and little or no fire control equipment. The figure used seems generous.

F. Naval Use. U.S. Naval use is about 2,400,000 per month and U.S. Naval practice is 100 per cent of spares for all seagoing equipment on shipboard plus extensive shore base stocks. It is most generous, we think, to assign the German Naval program about 20 per cent of the bearings used by the U.S. program, 500,000 per month.

Summarizing we get the following for the important military uses:

German Monthly Military Bearing Consumption

Military Item	Bearings per item, including spares	Production Rate End Item[1]	Monthly Bearing Use
Aircraft	1100	2500	2,750,000
Tanks	200	1000	100,000
Armored Cars	100	1000	100,000
Trucks	100	15,000	1,500,000
Fire Control Equipment and Artillery	-	-	250,000
Naval	-	-	500,000
Total Military Use			5,200,000

1. These figures are not OSS estimates of output but are extremely generous estimates used for the special purposes of this study.

At this point it is necessary to consider the reconciliation of estimates of German capacity and output made on the familiar SKF "standard" bearing and the numerical analogies which stem from the United States total numerical output figures. The "standard" bearing is an average bearing in which the capacity of a particular plant is stated by SKF engineers. Since it is based on the actual output of the plant and is a specific and weighted average of the capability of the plant it can be considered representative of the 1939-1940 output of that plant. It is our belief that we can rely on the comparability of the two types of figures we have used because we feel that German output in 1939 and 1940, when our estimates were largely made, was substantially converted for war. In addition we believe that although aircraft bearings, for example, are more precise than average peacetime bearings, they are also generally smaller.

IV. SOME TENTATIVE CONCLUSIONS.

The implications of this analysis, should refinement of the estimates and confirmation of the assumptions become available, are fairly clear. Either non-essential military and industrial and civilian use is almost half of German bearing output or a substantial cushion of production capacity exists. It may be that our capacity figures are too high or that the "standard bearing" is no longer an accurate method of calculating capacity. However, we believe it likely that further work on the absolute bearing requirements of the German military programs,

rather than continued use of a percentage consumption pattern applied to estimates of bearing production, will confirm our view of the necessity for re-evaluating the German bearing position.

Our tentative conclusions may not affect any conclusions as to the desirability of destroying German ball and roller bearing capacity or as to the vital need of the Germans for anti-friction bearings. Individual types and sizes of bearings may well be critical in Germany despite a comfortable general bearing position. The output of particular plants which are vulnerable to bombing may still be of tremendous importance to the Germans. On this point, we feel that the identification of plants as to the nature of their output in the aero-engine study is hardly on firm ground. Indeed one of the main conclusions of that study was that in general output of particular types of bearings was not concentrated in any one plant. Belief here is that fairly full lines of sizes are made in each plant with the possible exception of the newest plants. Machinery, even in those plants, would be flexible as to size of bearing produced.

In summary it seems to us that our analysis point to the necessity for a much more conservative conclusion as to the effects of the loss of output at Schweinfurt than the recent British JIC paper which stated that aircraft output would be affected in three months. Our central conviction is that further work on captured equipment will provide us with the data hitherto lacking and enable us to reconcile what at present seems a highly

paradoxical situation. The batch process and the probability that undamaged machines can be set up, either at Schweinfurt or in the other plants, to produce the critical bearing types and sizes, point toward the necessity of a more conservative appraisal of the effects of the heavy bombing program and a belief that substantial hindrance to military production can be achieved only by much greater damage to bearing production facilities.

APPENDIX - A.F. BEARINGS

A. A Note on the Identification of Buildings at Schweinfurt.

The identification of buildings in VKF works I and II in Schweinfurt by PR differs in some respects from that given to us by SKF men who had been through the plant before the war. Mr. Brodine an engineer i SKF had been in the VKF work in 1937. At that time according to him the VKF work II made all the ball and rollers but did not make the races or do any of the final assembling, the latter part of the process being done at work I.

The following piece of information may have significance in the identification of VKF buildings. Mr. Hughes, president of New Departure, was in Schweinfurt in 1939, New Departure being very closely associated with Fichtel and Sachs in the bicycle field. At that time, he was told by Mr. Sachs that a new large building being put up at the north west corner of VKF II (that is, the corner nearest Fichtel and Sachs) was to be the new ball forming plant. He himself did not go through all the VKF plant as they were reluctant to show him everything and he did not want to press them because he did not want their representatives to view the New Departure plants in America. In regard to the possibility of Fichtel and Sachs doing any bearing work, Mr. Hughes stated that in 1939 they were doing no bearing work;

they were , however, making small outboard motors in addition to their regular cycle work and he felt that if they switched to additional war work it would rather be to making motors and motor components than to making bearings.

All the industry people in this country agree that Mr. Homberg of SKF Sweden, who was in charge of VKF Schweinfurt until a few months ago but who has returned to Sweden, would be the only reliable source of information on the present set up of VKF. We understand that Mr. Waring of NEW was in Sweden to interview the SKF people. It is to be presumed that he has secured the relevant information. Mr. Homberg has by now perhaps returned to Germany as,according to a cable from Sweden,the Germans apparently threatened to confiscate the plants unless he returned to repair the damage done by the air attacks. Mr. Homberg is not a Nazi according to Mr. Batt.

A later cable from Sweden in reply to a cable sent from Washington stated that Homberg had returned to Germany and that SKF had been ordered by the government not to reveal any information on German requirements to any outsiders.